



Electric Grid Applications of the Texas Magnetometer Network

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Acknowledgments

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- Slides also include contributions from members of our research group at both TAMU and UIUC, and project collaborators such as CPI

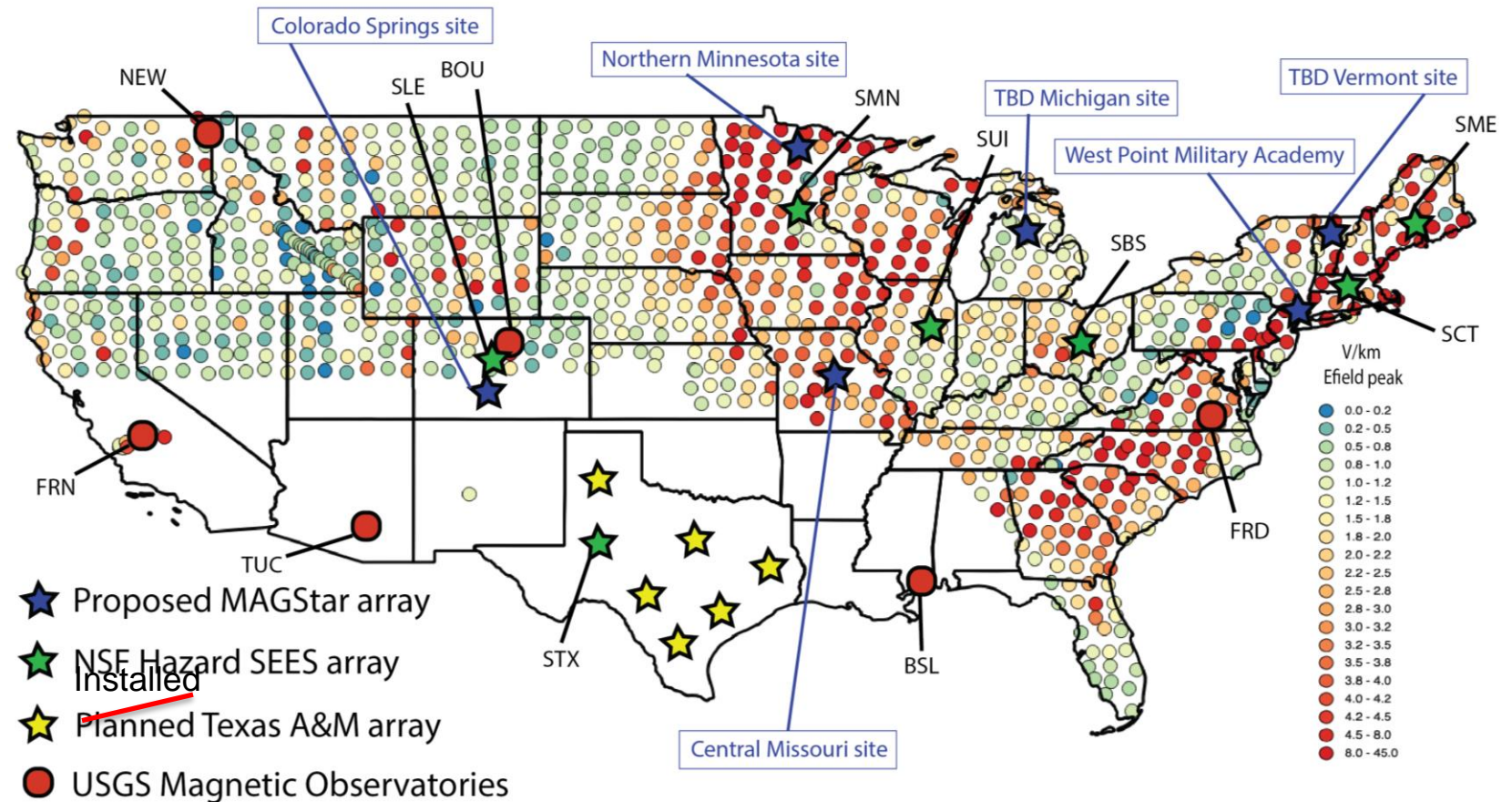
- Why a Texas Magnetometer Network?
- Key Features
- Applications
- Wrap-Up

Motivating Factors

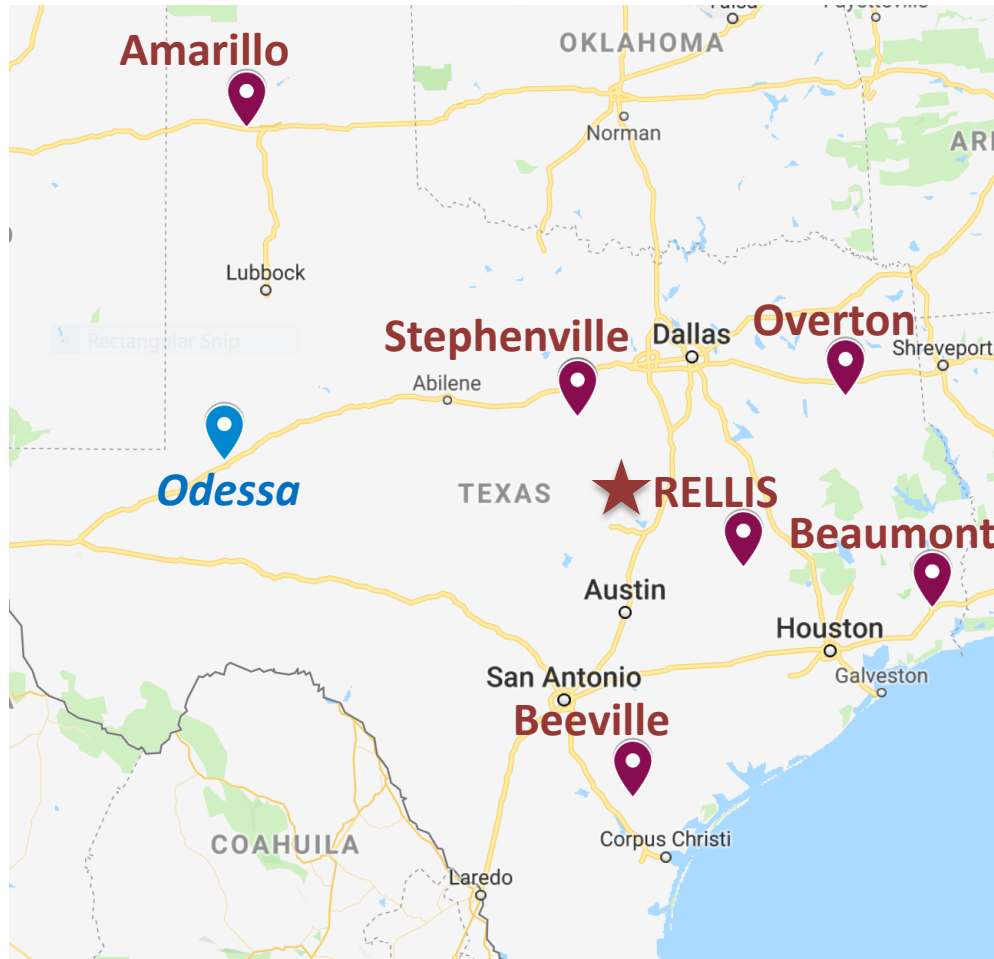


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- Improve understanding of Texas geophysics for GIC hazard analysis
 - High degree of uncertainty in available conductivity models
 - No models built specifically for TX; limits understanding of how GIC hazard varies between locations
- Few mags in the US, before NSF Hazards SEES and TAMU array



Texas Magnetometer Network



- Six magnetometers deployed across Texas, on A&M land
 - Seventh in W Texas associated with prior NSF Hazards SEES project
 - Collaboration with CPI
- Locations
 - Five Texas A&M AgriLife Research sites (Amarillo, Beaumont, Beeville, Overton, Stephenville)
 - One local (Bryan: RELLIS Campus)
- Papers have been published*

*K.S. Shetye, R.R. Kumar, C. Klauber, Z. Mao, T.J. Overbye, J. Gannon and M. Henderson, "Development and Electric Grid Applications of a Magnetometer Network," *IEEE Open Access Journal of Power and Energy*, Dec 2020

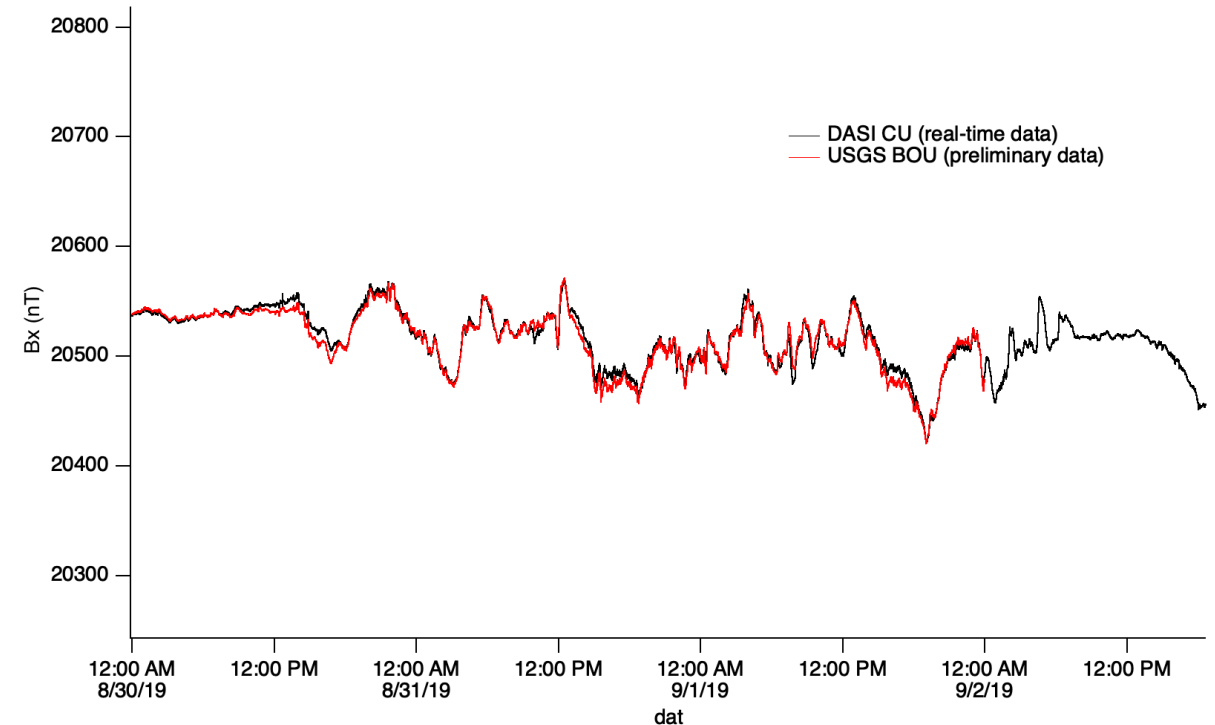
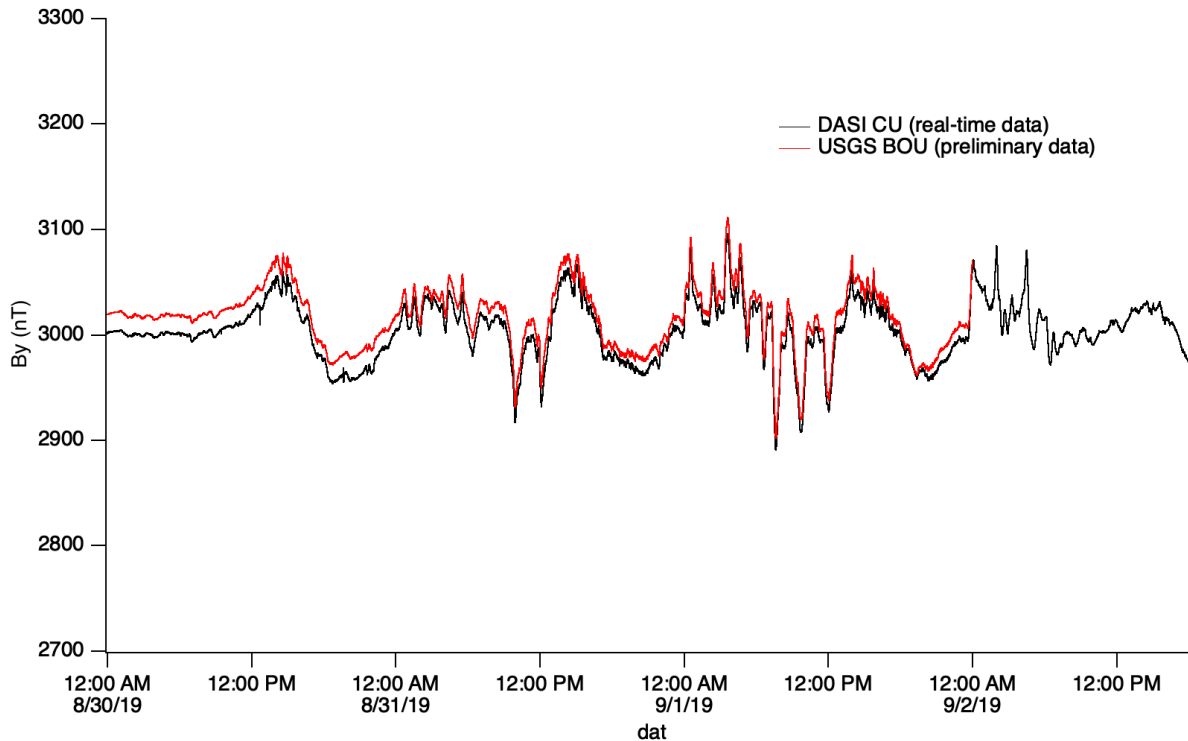
C. Klauber, K. S. Shetye, Z. Mao, J. Gannon, and T. J. Overbye, "Real-Time Monitoring Applications for the Power Grid under Geomagnetic Disturbances," *2020 IEEE Electric Power and Energy Conference (EPEC)*, Nov 2020.

- Real-time data delivery (fraction of a second latency)
 - 1-sec resolution
- Web-based data download in .csv format
- Real-time temperature correction
- Low-noise magnetic field measurements

Magnetometer Data Validation



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- Test installation of TAMU equipment in CU Boulder
- Comparison with BOU data

Magnetometer Setup



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Connect through
wireless access
points for secure
communication



Beaumont



Beeville



Autonomous
operation
(low power,
solar panels)

- Data can be made available to utilities
 - Real-time – situational awareness, control and mitigation
 - Historical – post event analysis, regulatory compliance
- Data can help fulfill R13 of NERC Standard TPL-007-4

“Each responsible entity shall implement a process to obtain geomagnetic field data for its PC’s planning area”

 - Web portal has been made available to ERCOT recently
 - Working on sharing with TX utilities through ERCOT
 - Some mags are very close to and in non-ERCOT footprints such as Beaumont (Entergy), and Amarillo (SPP)

Web Portal



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Menu

Dashboard

TAMU_Beaumont

TAMU_Rellis

TAMU_Beeville

TAMU_Stephenville

TAMU_Overton

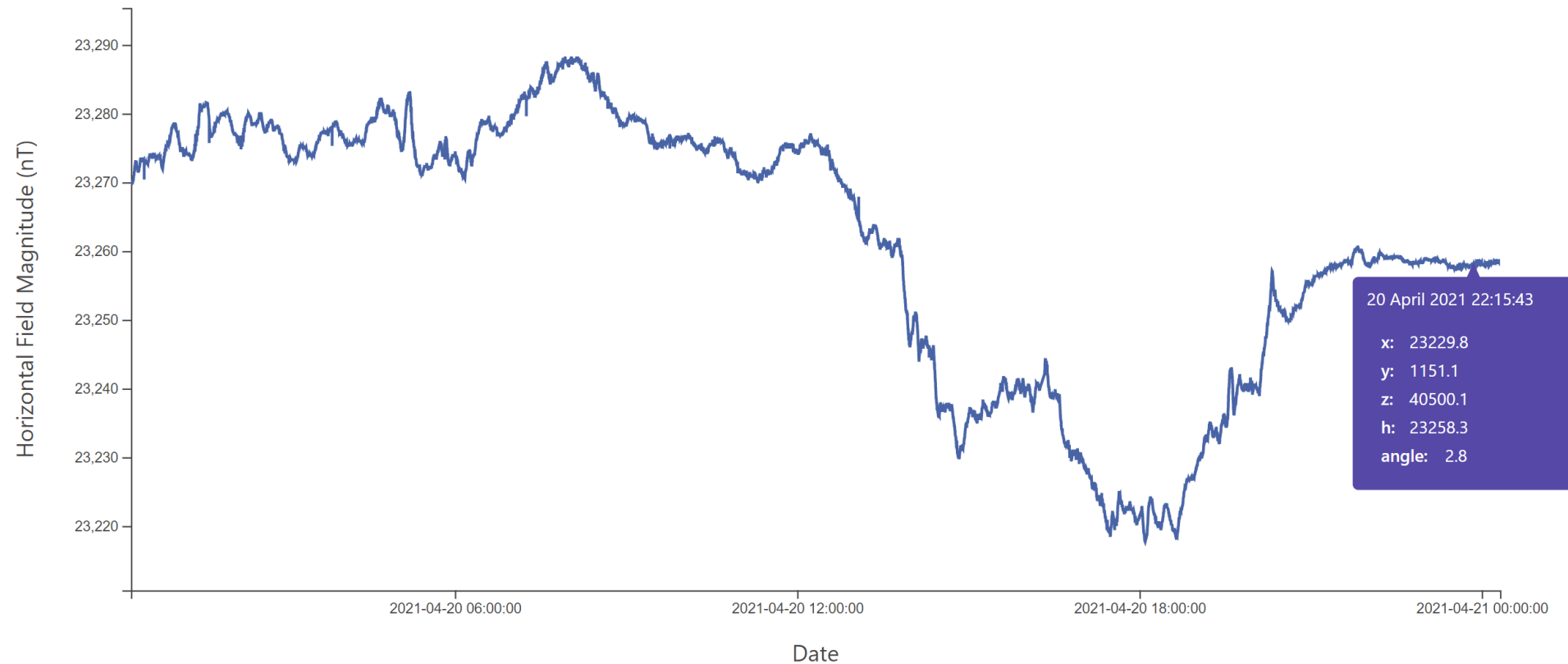
TAMU_Amarillo

TAMU_Rellis

College Station, TX 18.6°

20 April 2021 00:19:17 - 21 April 2021 00:19:17

Historical Mode

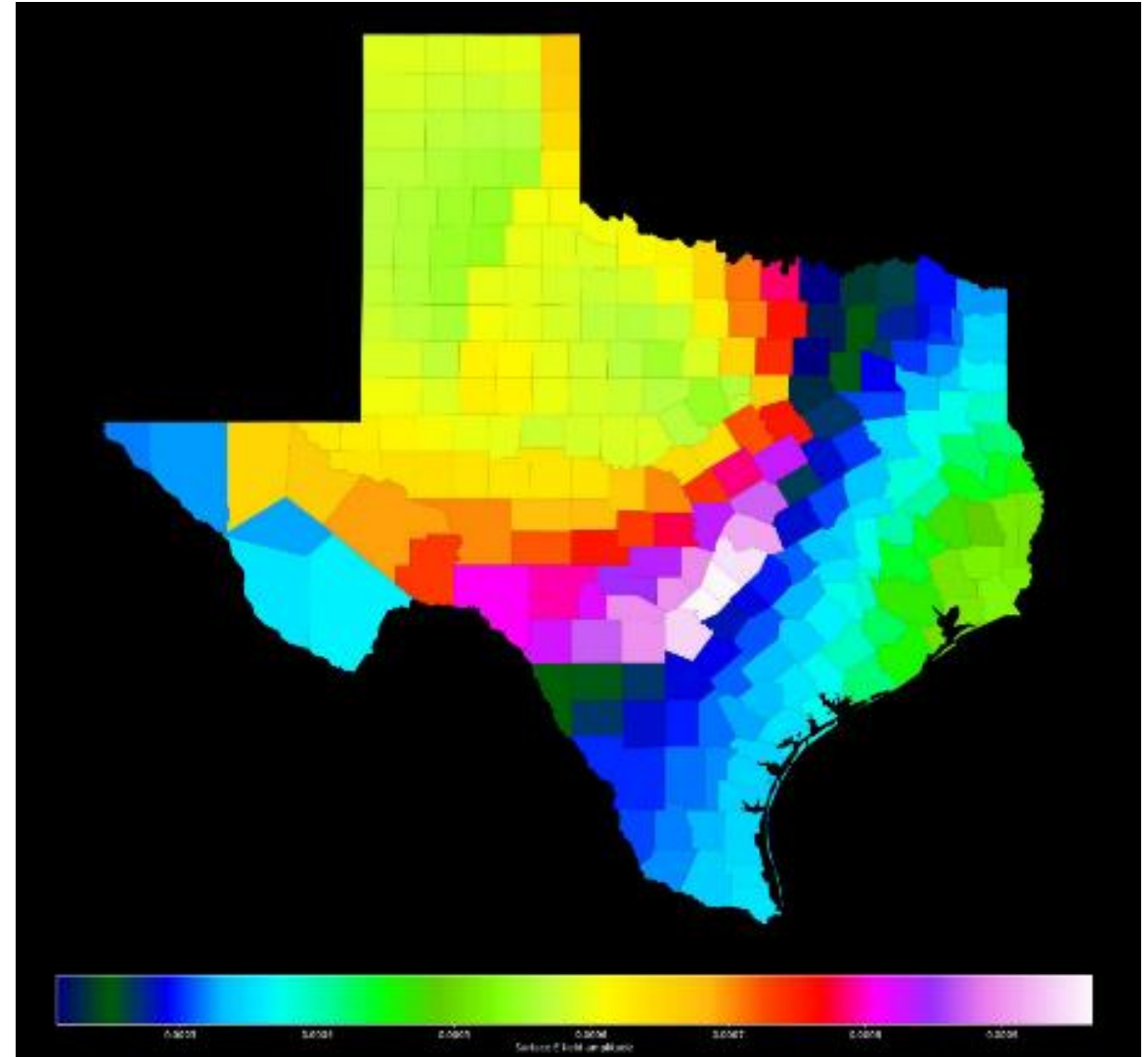


Real-Time Electric Fields



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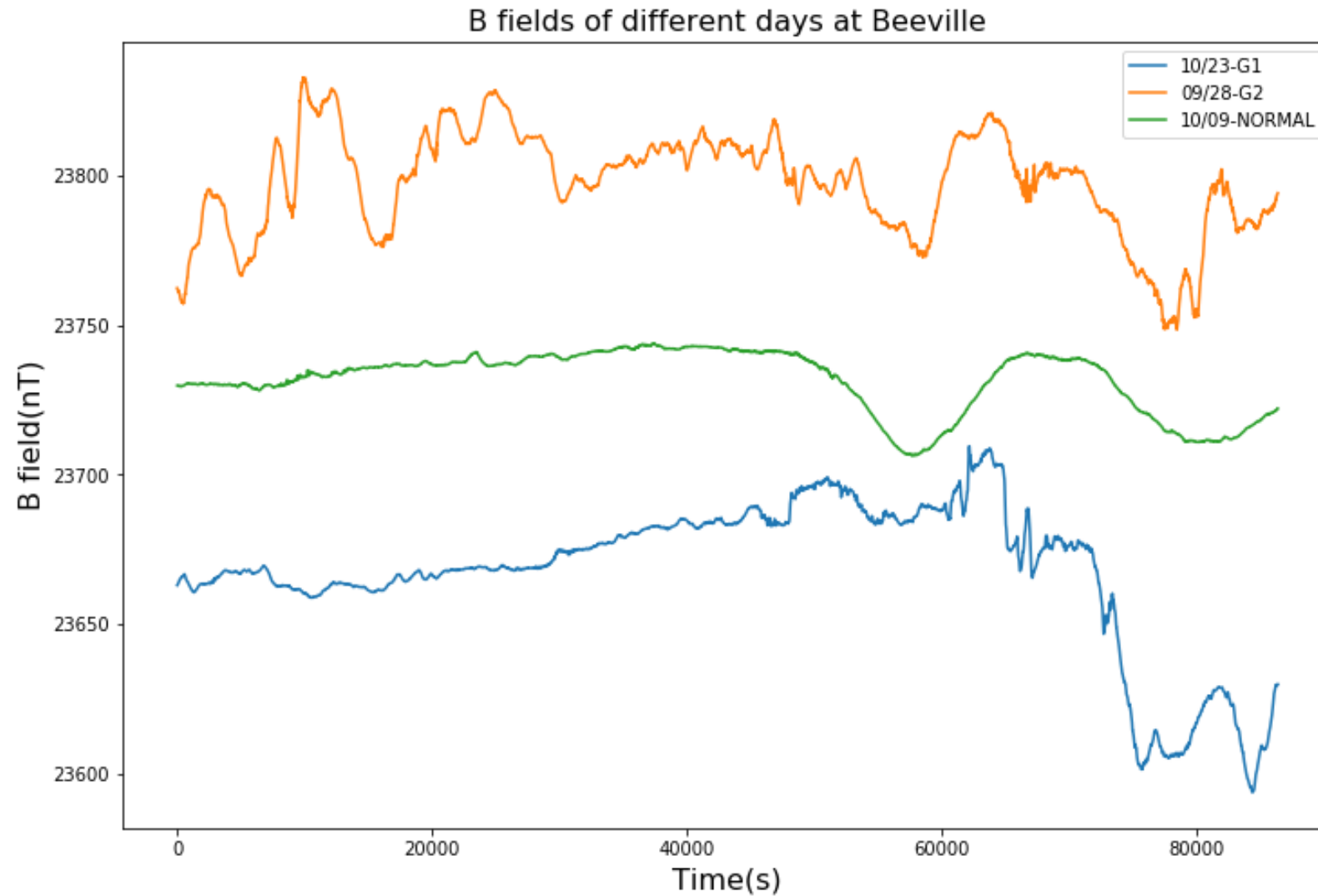
- We are also getting real-time electric field data (based on our magnetometer data) that can be made available
 - 1 min resolution
 - NERC TPL-007 conductivity model



Magnetic Field on Different Days



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Electric Field on Different Days



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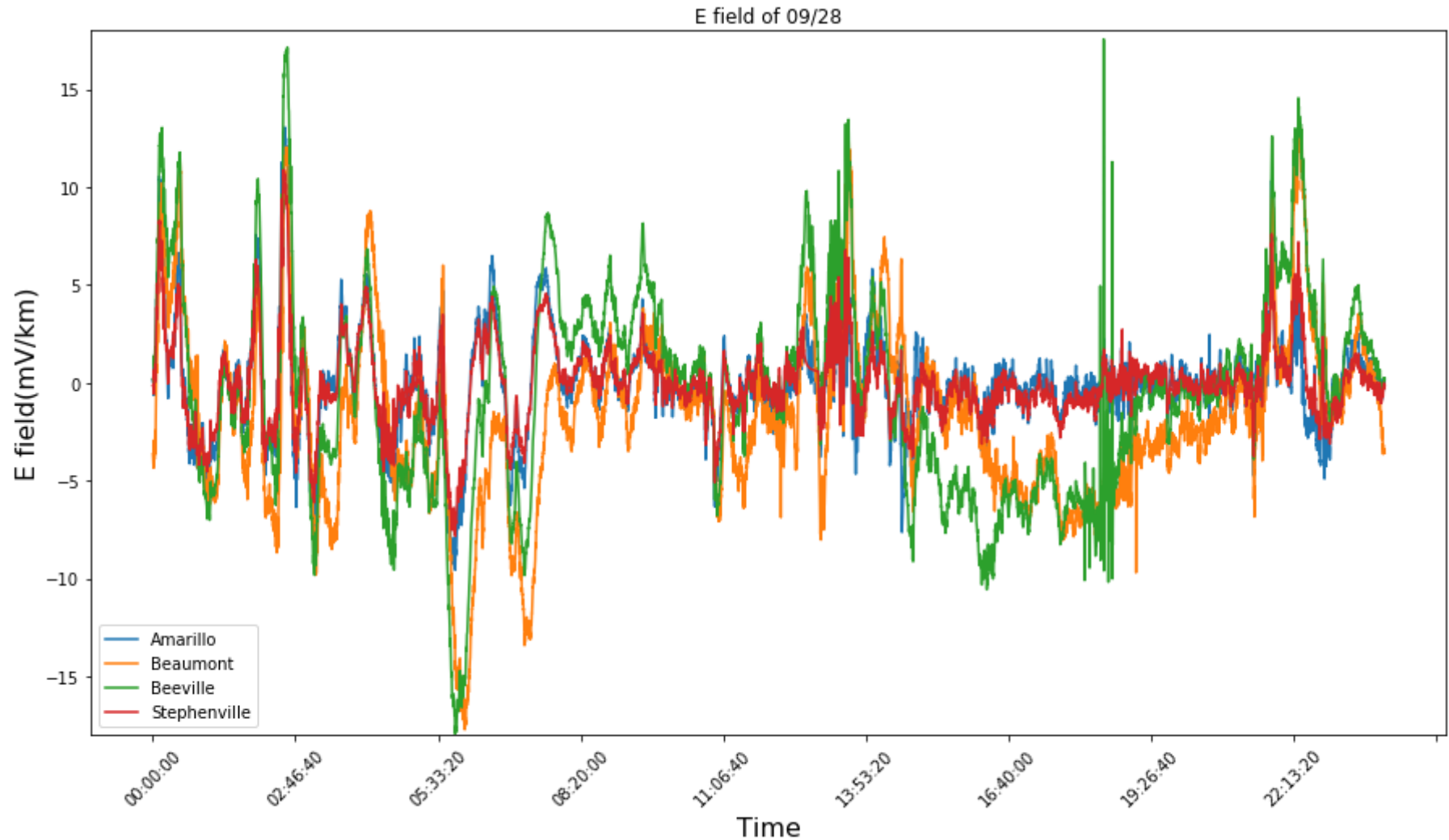
G2 Event – Electric Fields



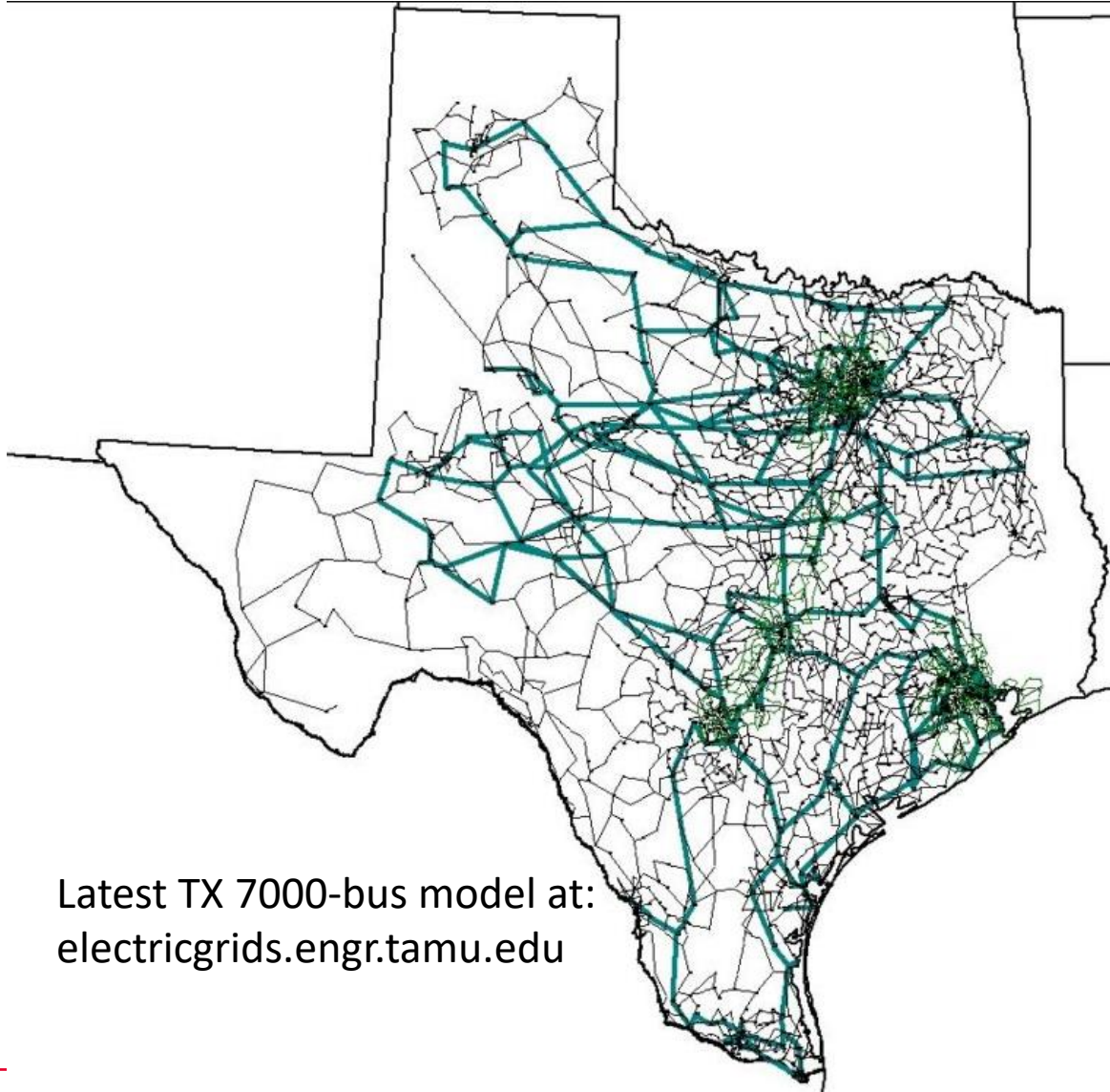
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- Beeville:
Near Corpus Christi (SE coast of TX)
- Beaumont:
TX – LA border
- Stephenville:
Near Dallas

G2 Peak:
~20
mV/km



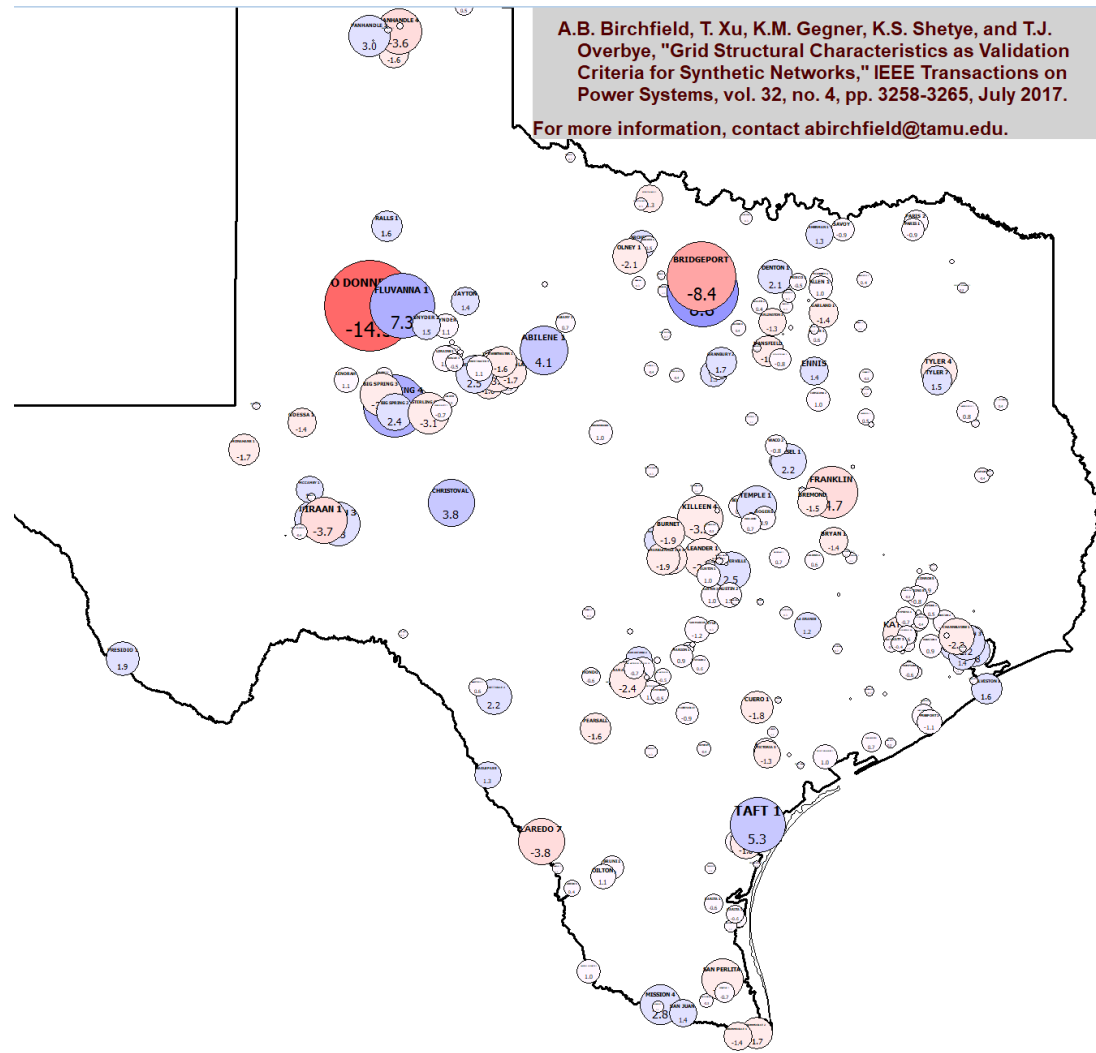
Real-time GLC Visualization



Latest TX 7000-bus model at:
electricgrids.engr.tamu.edu

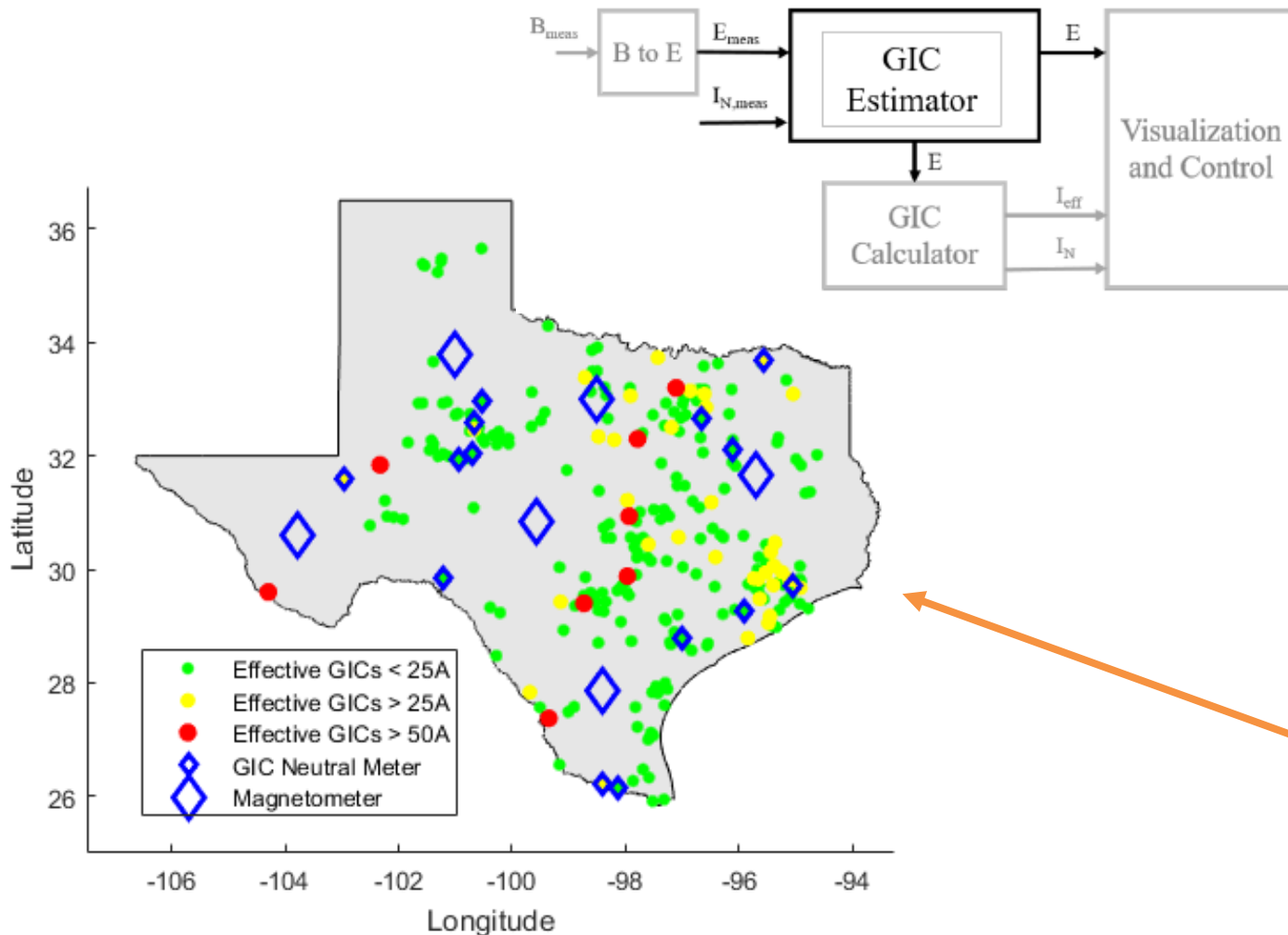
- Goal is to provide situational awareness for GMD operations
 - PowerWorld Dynamic Studio for emulating real-time grid operations
- Grid is modeled using synthetic but realistic model of the TX grid
 - Actual grid information is confidential (CEII); research results are not publicly available
 - We have created synthetic grids (for entire US) using statistical properties of actual grids

Real-time GIC Visualization



- Real time E-field input per min
 - GIC values calculated in the model
- Circles show the GIC values at each substation neutral
 - Size of circle and intensity of color proportional to GIC magnitude
 - Blue (positive) indicates current going from the grid into the ground
 - Red (negative) indicates current coming into the grid from the ground

Real-time GIC Estimation



In the real world, actual grid would replace the grid model

- GICs not known unless measured
- Increasing deployment of GIC monitors, still sparse
- GIC Estimation algorithms*
 - Power system state estimation well known problem; but many measurements are available
 - Simulation example, good GIC estimation results with 6 mags and 15 GIC monitors

*C. Klauber, K. S. Shetye, K. Davis, and T. J. Overbye, "A GIC State Estimator for System Monitoring under Geomagnetic Disturbance," *IEEE Transactions on Power Systems*, vol. 35, no. 6, pp. 4847-4855, 2020.

G. Juvekar, C. Klauber, K. Davis, T. J. Overbye, and K. S. Shetye, "A GIC-Inclusive State Estimator for Power System Awareness during Geomagnetic Disturbance Events," *IEEE Transactions on Power Systems*, 2020.

- Working with local utility to install GIC monitors
 - Useful for research on estimation, ground conductivity
- Transformer GIC measurements from utilities around TX will help improve GIC system model for the entire grid
 - Looking for industry partners
 - We are quite experienced with CEM data use for research
- Insights to gain from closely spaced array of mags
- Potentially connect GIC estimator to an industry-grade Energy Management System (EMS)

RELLIS CIR Control Room Lab



- Power Grid Operations Research and Education
- Give users experience of operating the grid in scenarios such as GMD
 - Students, professionals
 - Interactive simulations; users take control actions to mitigate GMD impact
 - R&D of monitoring, visualization, and control applications

GMD Short Course



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- 2-3 days, first offered in April 2019 at the Smart Grid Control Center at RELLIS
- Next one TBD, likely Fall 2021
- Details at <https://epg.engr.tamu.edu/electric-grid-impacts-of-geomagnetic-disturbances/>



Last GMD course full! (24 participants, mostly industry, national labs, etc.)

Thank You!



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Questions?

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